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Oxygen saturation in healthy newborns; influence of birth weight and mode of delivery

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Abstract

Aims: To study the normal levels of oxygen saturation (SpO_2) in healthy newborns during the first 24 h of life and the possible relationship to birth weight and mode of delivery.

Methods: SpO_2 was measured by pulse oximetry on one occasion between 2 and 24 h after birth in 6805 asymptomatic newborns with gestational age $\geq$34 weeks and birth weight $\geq$2500 g.

Results: The average SpO_2 for all children was 98.0% (SD 1.4). SpO_2 was negatively related to birth weight and ranged from 98.2% (1.4) in children with birth weight 2750–2999 g to 97.6% (1.3) in children weighing $>$4500 g ($P<0.001$). No relationship exists between SpO_2 and gestational age or gender when correcting for birth weight. SpO_2 was independently related to mode of delivery, with higher levels in children born by cesarean section (98.3%; 1.3) than by vaginal delivery (98.0; 1.4; $P<0.001$). There was no relationship between SpO_2 and the interval from delivery to measurement.

Conclusions: In healthy newborns, levels of SpO_2 measured between 2 and 24 h of life are negatively related to birth weight and related to mode of delivery. However, the variation was within a small range and probably has few implications for the routine use of SpO_2 in newborns.

Keywords: Birth weight; cesarean section; newborns; oxygen saturation.

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Introduction

Pulse oximetry is an easy and non-invasive method for measuring arterial oxygen saturation (SpO_2) in newborns [2], and is commonly used to evaluate newborns with cardiopulmonary symptoms [5, 12]. Several studies evaluated the normal reference values for SpO_2 during the first 24 h of life. During this period newborn infants adapt their circulation to extrauterine life. After an initial increase in SpO_2 during the first minutes of life, SpO_2 seems to be stable until 20–24 h of life [2, 6, 8, 10, 11]. Most studies find that mean SpO_2 is about 97–98%, with the normal range from 94 to 100% [7]. However, SpO_2 is lower in children born at high altitude [1, 3].

Recent studies have suggested that SpO_2 measured during the first hours of life may be an effective screening tool for congenital heart disease [9, 13]. If the measurement of SpO_2 is suggested as a routine in newborns, more knowledge about the normal variation of SpO_2 during the first day of life will be of value. Several perinatal factors such as birth weight, gestational age (GA), gender or mode of delivery could possible influence the levels of SpO_2 in newborns. However, few studies have included a large numbers of newborns to assess whether these variables correlate with the levels of SpO_2 during the first 24 h of life. As part of a Norwegian multicenter study evaluating the efficacy of pulse oximetry as screening for congenital heart disease, SpO_2 was measured in a large number of newborns in our hospital [9]. The objective of the present study was to include birth weight, GA, mode of delivery and gender, to analyze if these variables have any influence on levels of SpO_2 in healthy newborns.

Subjects and methods

Stavanger University Hospital has the only maternity ward for the population of South Rogaland Norway (306,000 inhabitants), with about 4400 children being born annually. Very few home births are registered in the area. We intended to include all healthy newborns born at the hospital during 2005 and 2006.

Newborns born at $\geq$34 weeks GA and weighing $\geq$2500 g admitted to the nursery from the maternity ward were included in the final study. Children with symptoms of disease or receiving supplementary oxygen were admitted to the neonatal intensive care unit and therefore excluded.

SpO_2 was measured postductally (foot) by the pulse oximeter RAD-5v (Masimo Corporation, Irvine, California, USA) measuring functional SpO_2 [9]. The measurement was performed by the nurse responsible for the child, and all the nurses involved were

instructed how to use the pulse oximeter. The probe was attached for at least 2 min until the highest stable level with a good waveform was registered. The nurses were instructed to preferentially perform the measurement between 4 and 5 h after births, but any time between 2 and 24 h was permitted. The time for measurement was not influenced by the activity state of the child.

The value of SpO_2 as well as birth weight, mode of delivery, GA and the time of measurement (hours after delivery), were registered. Gender and mode of delivery were only registered for children born in 2006. We included children with the first SpO_2 measured $\geq$95%. If the first SpO_2 was $<$95%, another measurement was performed within 2–3 h, but these children were not included in the final analyses.

Data were collected as a part of the Norwegian multicenter study which was approved by the ethical committee for medical research. Parents were given oral and written information, however, the ethical committee approved that a written consent was not obtained.

Data were analyzed by the SPSS 15.0 statistical package (SPSS Inc, Chicago, USA). Comparisons of two independent groups were done by *t*-tests and of multiple groups by one-way ANOVA. Comparisons of SpO_2-levels in different groups with correction for additional factors, e.g., comparison of weight groups corrected for GA and time, were done using multinomial regression. All tests were two tailed and the level of significance was set at 5%.

Results

A total of 8550 children were born at the hospital during the two years. Of these, 7129 children were admitted to the nursery and registered in the database (the remaining referred to the neonatal intensive care unit or data missing). Ninety-six children were not included due to low birth weight or GA. For 229 children (3.2%) the first SpO_2 was $<$95% and they were not included in the further analyses. However, 183 of these children had SpO_2 $\geq$95% when measured for the second time within a few hours.

A total of 6805 children fulfilled the criteria for inclusion in the final analyses. Of these, gender was registered in 3520 children (1773 boys and 1747 girls), and information about GA was available from 5474 children. The median age at the time for measurement of SpO_2 was 5 h (range 2–24 h, interquartile range 3 h). The median birth weight of the children was 3597 g (SD 468 g) and the median GA was 40 weeks (mean 39.5 weeks).

The mean oxygen saturation for all children was 98.0% (SD 1.43). Mean levels were slightly lower in boys [97.9; 97.9–97.9 (95% CI)] than in girls (98.1; 98.0–98.2) ($P<0.01$), but no significant gender difference existed when corrected for weight.

The mean SpO_2 with 95% CI or SD for different groups of birth weight is given in Figure 1 and Table 1. When analyzed by one-way ANOVA there was an overall significant decrease in oxygen saturation with increasing birth weight ($P<0.001$) (Figure 1). No significant differences were found between SpO_2 in one weight group and the adjacent weight group.

SpO_2 was also significantly related to GA when analysed by one-way ANOVA ($P=0.01$). However, this difference was not evident when included in multinomial regression analysis together with birth weight.

SpO_2 was significantly higher in children born by cesarean section than in those delivered vaginally, whereas the weight was similar in the two groups (Table 2). When analyzed by multinomial regression, both weight ($P<0.001$) and delivery mode ($P<0.001$) influenced SpO_2 independently. The average time from birth to measurement did not differ between those with different delivery modes (Table 2).

If the children with SpO_2 of $<$95% at the first measurement and $\geq$95% at the second measurement were

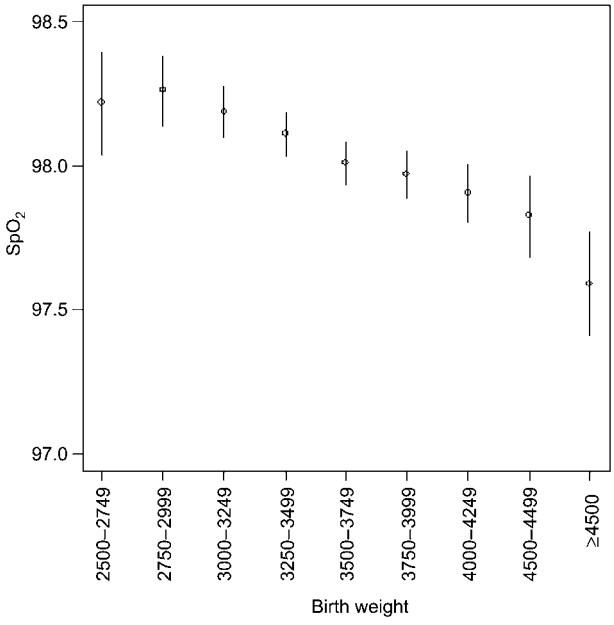

Figure 1 Mean oxygen saturation (SpO_2) (mean; 95% CI) in relation to birth weight (g), measured from 1 to 24 h of life in 6805 healthy newborns $\geq$34 weeks' gestational age and $\geq$2500 g.

Table 1 Oxygen saturation (SpO_2) measured postductally between 1 and 24 h after birth in healthy newborns with gestational age $\geq$34 weeks and birth weigth $\geq$2500 g. Relation to birth weight.

Birth weight (g)	Number	Mean SaO_2	SD
2500–2749	214	98.2	1.4
2750–2999	491	98.3	1.4
3000–3249	883	98.2	1.4
3250–3499	1312	98.1	1.4
3500–3749	1389	98.0	1.4
3750–3999	1188	98.0	1.5
4000–4249	715	97.9	1.4
4250–4499	390	97.8	1.5
$\geq$4500	222	97.6	1.4

Table 2 Oxygen saturation (SpO_2), birth weight (g) and time from birth to measurement (h) of SpO_2 in healthy newborns with gestational age ≥34 weeks and birth weight ≥2500 g. Relation to delivery method. Results are given as mean; 95% CI.

	Cesarean section	Vaginally	P-value
Number	182	3339	
SpO_2	98.3; 98.1–98.5	98.0; 97.9–98.0	<0.001
Weight	3589; 3508–3671	3593; 3577–3610	0.9
Sampling time	6.6; 6.0–7.2	6.3; 6.2–6.5	0.5

included in final analyses, the significance of the results was not influenced (data not shown).

There was no relationship between SpO_2 and the interval from delivery to measurement (P = 0.9). The time for measurement was not available in 269 of the recordings. For the remaining recordings, 85% were performed from the 4th–8th h. The results of the measurements were stable during these hours as well.

Discussion

We demonstrated in this study that levels of SpO_2 during the first day of life were related to birth weight and mode of delivery in healthy newborns. Mean SpO_2 was higher in children with a low birth weight and varied from 98.3% in those with a birth weight of 2750–2999 g to 97.6% in those with a weight above 4500 g. Further, SpO_2 was higher in children born by cesarean section than in those delivered vaginally, and this difference did not explain why SpO_2 was related to birth weight. SpO_2 was not related to GA and did not differ between boys and girls after correction for birth weight. This is to our knowledge the first study of the relationship between SpO_2 and birth weight and mode of delivery in a large number of healthy newborns.

The mean SpO_2 measured in all children was 98% which is similar to other studies [10]. However, Levesque et al. found a lower mean SpO_2 of 97.% in 718 healthy newborns [7]. The reason for this difference is not known, but differences in methods of measurements may possibly influence the results.

It has been shown that SpO_2 rises during the first minutes of life to reach stable levels within few minutes [2, 6]. O'Brien et al. found that levels of SpO_2 were stable thereafter until a minor decline during the 20–24 h of age, whereas Levesque et al. found a slight increase in SpO_2 from admission to the nursery to 24 h postnatally [7, 10]. We did not perform longitudinal measurements during our study, but our results and the large number of data in our study strongly suggests that levels of SpO_2 do not vary significantly by age from 2 to 24 h postnatally.

The reason for the relation between birth weight and SpO_2 in this study is not known. As weight increases with GA, differences in SpO_2 could possibly be related to hemodynamic differences related to GA. However, we found no relation between SpO_2 and GA when corrected for weight, demonstrating that the impact on levels of SpO_2 by birth weight is independent of GA. Other studies have shown that in premature children the time to reach a stable SpO_2 is longer than for term babies [2, 6], but no studies have to our knowledge demonstrated that SpO_2 varies with GA in newborns at GA ≥34 weeks.

It has been demonstrated that children born by cesarean section have lower levels of SpO_2 during the first minutes of life, probably due to increased amount of lung fluid [4, 11]. However, this difference was equalized within a few minutes [4, 11], and we have found no other studies evaluating SpO_2 later during the first 24 h of life related to delivery mode. We hypothesized that mode of delivery could affect both birth weight and SpO_2 and thereby explain a possible relation between birth weight and SpO_2. This was not true. Children born by cesarean section are a selected group, and it is possible that this selection involves unknown factors other than weight influencing levels of SpO_2. However, our results demonstrate that increased lung fluid after cesarean section does not lower the level of SpO_2 from 2 to 24 h of life.

We chose a relative high limit for a normal value of SpO_2, and lower levels may be considered normal [7]. However, this level was used as cut-off in the main multicenter study after demonstrating a SpO_2 of 95% to represent the 2.5 centile for distribution of the measurements [9]. Only a small number of children had SpO_2 of <95% at the first measurement and ≥95% at the second measurement. Including these children in the final analysis did not influence the results and conclusions of the present study.

Even though we have demonstrated statistical differences between groups related to birth weight and mode of delivery, any clinical implication for this is not known. The difference of the means between weight groups with the highest and the lowest SpO_2 was 0.7%, and between different delivery methods 0.3%. For all children this was a variation within the normal range. The relationship to birth weight may probably be considered as a physiological phenomenon without known implications for the routine use of SpO_2 measurement in newborns. Further, we also confirmed that levels of SpO_2 are stable when measured from 2 to 24 h of life, and altogether our results confirm that measurement of SpO_2 is an easy and reliable test in newborns.

We conclude that in healthy newborns, levels of SpO_2 measured between 2 and 24 h of life are negatively related to birth weight and higher in children born by cesarean section than in children delivered vaginally. The

differences are within a small range and might not have implications for the routine use of SpO_2 in newborns. However, our observations may have relevance when birth weight and delivery mode are included in future studies evaluating levels of SpO_2 in newborns.

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